Additional Observations of the Disappearances and Reappearances of the Rings of Saturn in 1907–8, *made with the* 40-*inch Refractor of the Yerkes Observatory.* By E. E. Barnard.

1907 Nov. 23—with 12-inch telescope, $6^h\ 15^m$, power 150±. I could see the two condensations on the preceding part of the ring. They were fairly distinct, but faint. Could scarcely see them on the following side.

$7^h\ 30^m$—using a higher power. The ring and condensations were not so well seen. A satellite closing in following, mixed its light with the condensations on that side. With the low power could see the two condensations on the preceding ansa very distinctly. They appeared equal in brightness. The inner one joined up to the planet with but little change of brightness. There was no doubt but that the following ansa and condensations were fainter than the preceding. The satellite interfered, however. The sky was clear and good, but the image was unsteady. The trace on the ball was apparently dark and without irregularities.

Nov. 24. $5^h\ 11^m$. The condensations were easy. There were two satellites, one preceding and one following, that interfered. The condensations were of equal brightness, both preceding and following. The inner one preceding was bright to the ball. The entire ring was visible with or without the occulter. Seeing = 2 (on a scale of 5). Lost in clouds.

$8^h\ 46^m$. Thinning down near Saturn. The following ansa was certainly the brighter. There was a faint satellite (Mimas) following the following end of the ring. The outer condensation near it was twice as bright as the satellite. Seeing = 1. The full extent of the ring was quite conspicuous when best seen.

$9^h\ 8^m$—with the 12-inch telescope. Could see the condensations. Both Mr. Sullivan and I decided that the following side was the brighter. Seeing poor with 12-inch. (Back to 40-inch.) There was no question but that the following ansa was the brighter. The ring between the condensations was faint. The outer condensation following was two times as bright as the faint satellite following (Mimas). In each case the outer and inner condensations were of equal brightness. Seeing very bad.

Nov. 25. $4^h\ 55^m$. The condensations were of equal brightness. The space between them was almost discontinuous.

$5^h\ 25^m$. Distance between the centres of the preceding condensations—

$$4''{\cdot}60\ (6)\ [4''{\cdot}44].$$

Distance between the centres of the following condensations—

$$4''{\cdot}51\ (6)\ [4''{\cdot}35].$$

Seeing very poor. Went to the 12-inch telescope. Could faintly see the rings and condensations—very faint compared with the view in the 40-inch.

Nov. 26. $5^h\ 55^m$. Seeing fair for moments. The condensations

were very bright, but the ring between them was very faint, and all but discontinuous.

$6^h\ 25^m$. The small satellite following was the same brightness as the inner condensation, but very slightly brighter than the outer one. The following ansa was considerably brighter than the preceding. I could see the ring beyond the outer condensation following,—I think, all of it, but it was extremely faint. The condensations were about the thickness of the diameter of the bright satellite following. The inner condensations were a little brighter at their outer ends. Seeing = 3.

$6^h\ 45^m$. The bright satellite was half a magnitude brighter than the outer condensation.

$6^h\ 50^m$. The outer condensation was exactly midway between the satellite and the following limb. The following ansa and condensations were certainly brighter than the preceding. They were all conspicuous with the planet unobscured. When seen best the condensations appeared to become narrower.

Nov. 28. $5^h\ 4^m$. Seeing very poor. The ring and condensations were conspicuous.

$5^h\ 24^m$. There was a small satellite (Tethys) just north of the ring, and about midway between the condensations following. I think the following ansa was the brighter.

$6^h\ 49^m$. There was a small satellite between the two condensations preceding, nearer the outer one. There was a bright satellite close preceding the end of the ring in line with it. There was a similar satellite at the preceding end of the ring a little north. These satellites were half a magnitude brighter than the condensations. I think the inner condensation following was slightly brighter than the outer one.

$6^h\ 59^m$. Seeing very poor. There was a very faint satellite (Enceladus?) then visible at the preceding end of the ring, close south following the brighter satellite. The seeing was very poor. I could not make out any details on the ball.

$8^h\ 54^m$. The seeing better, though the planet was low. The following ansa was, I think, the brighter. The inner and outer condensations were of the same brightness. The inner ones joined up to the ball with almost full brightness. The space between them looked to be a little less than on some previous nights.

Dec. 3. $7^h\ 42^m$. The condensations were quite bright.

Distance from preceding condensation to following limb—

$$27''{\cdot}25\ (8)\ [26{\cdot}63].$$

From preceding limb to outer condensation—

$$7''{\cdot}55\ (8)\ [7{\cdot}38].$$

The inner condensation was bright up to the planet. Could not make much out of it on account of the blurring. I don't think there had been any change in the condensations. They were brighter than the small satellite (Tethys?) preceding.

Dec. 5. $5^h\ 46^m$. The condensations were bright in moments of steadiness. The following ansa was the brighter.

$6^h\ 11^m$. I went over to the 12-inch telescope. The seeing was very poor. I could faintly see the following ansa, but could get only feeble traces of part of the preceding ansa. I could not be certain of seeing the condensations. Used low and high powers. The trace of the ring on the ball, or the shadow, was fairly well seen.

Back to 40-inch. The ansæ were conspicuous without occulter, as were also the condensations, though the seeing was very bad.

$6^h\ 21^m$. In moments of steadiness could see the ring continuous between the two condensations.

Dec. 10. $7^h\ 50^m$. Through clouds, seeing poor. The ring and condensations were easy. A small satellite was 3″–4″ following the following end of the ring. The outer condensation was brighter than this satellite.

Dec. 12. $4^h\ 38^m$. The definition was fair in moments. The ring and condensations were quite easily seen.

$4^h\ 58^m$. Seeing = 3. The ring was easily continuous between the condensations. Could see the ring beyond the outer condensations as a slender thread of light.

Distance from preceding limb to outer condensation,	7″·78 (6) [7″·73]
,, following ,, ,, ,,	7·84 (6) [7·79]
Length of outer condensation following,	2·30 (7) [2·28]
Width of space between condensations following,	2·32 (7) [2·30]

The ring and condensations following seemed to be brighter than those preceding. Sometimes the central part of the outer condensation, following, looked like an ill-defined satellite. A sketch showed it to be 2 to 3 times as long as it was broad. The inner condensation following was continuous up to the ball, but there was a brighter place at its outer end. The outer and inner condensations seemed to be of equal brightness. The ring between them was 6 or 8 times as faint as the condensation and looked much thinner. I could not see anything of the shadow of the ball.

$5^h\ 45^m$. The seeing has been 3 all along. The thickness of the outer condensation following was $\frac{1}{3}$ or $\frac{1}{4}$ its length. A sketch shows that close up to the ball the following inner condensation was quite faint for a second or so.

$7^h\ 6^m$. Dione was in conjunction close north with the outer condensation following. A small satellite (Enceladus?) following the following end of the ring was several times fainter than the condensations.

Dec. 25. $4^h\ 48^m$. The condensations, and the ring in general, were easily visible, but they were much thinner than at the last observation. Could see the full length of the ring. It was very narrow and faint at the ends beyond the outer condensation. The ring on both sides could be seen between the two condensations, though faint.

5^h 8^m. The inner condensation was bright nearly up to the ball, but, perhaps by contrast, it was faint near the ball. Seeing = 3. The trace of the ring on the sky was about on a line with the south edge of the shadow on the ball. The seeing was not quite good enough to tell if the shadow of the ring was irregular. It appeared clear and straight in moments of best seeing. A sketch says that the following inner condensation was not continuous close to the ball.

Estimated with the micrometer wire. The thickness of the condensations, or the ring at these points, was about $1\frac{1}{2}$ times the thickness of the wire, while the outer slender end of the ring was perhaps $\frac{1}{2}$ or $\frac{1}{3}$ the thickness of the wire [thickness of the wire $= 0''\cdot1$].

5^h 38^m. A small satellite was at this time exactly midway between the condensations. It was about one diameter of itself south of the line of the ring. The ring at the following side was not continuous up to the ball, but there was a faint place from the ball out for, say, $1''$. Question if this was the shadow of the ball on the ring. I could not be certain of this effect at the preceding side.

1908 Jan. 2. 5^h 50^m. The ring was very thin. There was a satellite at each end. The one following was very close to the ring. There was a very faint satellite close north of the ring, half way out, following. Seeing = 3. Without occultation it was almost impossible to see any trace of the ring on the sky. The condensations were feebly seen as slightly brighter parts of the ring. The ring and condensations were slightly brighter than the faint satellite, but were much less bright than the satellite at the following end of the ring. Same at 6^h 30^m.

Jan. 5. 5^h 0^m. The sky good. Seeing = 2. Not dark enough to see the ring.

5^h 10^m. Could see the ring very faintly with the occulter.

5^h 20^m. The sky was not entirely dark, yet could see the ring faintly, but not well.

5^h 40^m. The ring was very faint and quite thin. I think there was a feeble intensification of the ring at the places of the condensations; that is, it was possibly very slightly brighter at those points, but not thicker. The shadow of the ring on the ball was black and strong. The ring was much more difficult than on Jan. 2. I could not see anything of it without the occulter.

Jan. 6. 5^h 0^m. The sky too bright to see the ring. Seeing very poor.

6^h 0^m. A close watch was kept until this time with occulter. The seeing had steadied a little. During the best moments could not see anything of the ring. Seeing at best = 2. There was considerable glow from want of steadiness. Watched at both sides of the planet. It is possible that with better seeing I might have seen it, but it is doubtful. It must have been excessively faint.

Then went to the 12-inch telescope, but the seeing was poor. Tried high and low powers, but could not see anything of the ring.

Jan. 7. $5^h\ 15^m$. Seeing = 2. The ring was quite easily visible by occultation. It was linear, but rather faint on the following side. On the preceding side could see it well. There was a bright satellite at the preceding end of the ring. The ring must have been much brighter than on the 6th, for I could see it when the seeing was worse than it was at times on that date —when I could not see it at all. It looked hazy and ill-defined. There were no traces of condensations. It was a straight bar, its full extent perfectly uniformly illuminated clear to the end. It was of an ashy color, rather thickish and fuzzy.

$5^h\ 30^m$. There was a faint satellite 6″ or 8″ preceding the preceding end of the ring. It was just as bright as the ring. The sky hazed over. Went to the 12-inch telescope with Mr. Fox. He got a glimpse of the planet in a clear place between the clouds, and saw the ring. Thick sky prevented my seeing the ring with the 12-inch. Moonlight made the hazy sky too bright.

Jan. 8. $6^h\ 15^m$—with 12-inch telescope. The planet seen through break in clouds. Could see the ring faintly both following and preceding. Seeing poor—haze and clouds.

From these observations it would appear that the Earth must have passed the plane of the ring sometime between 1908 January, 5 days $6^h\ 0^m$ and January 7 days $5^h\ 15^m$. Perhaps this occurred not far from the time of the observation of January 6.

The observation of January 7 would seem to indicate that the plane had already been passed some hours before, from the distinctness with which the ring could be seen at that time.

The observation of January the 6th, though not under the best conditions, again showed how thin the ring must really be, for it was not visible with the light of the planet occulted.

I think, however, a more effective criterion of its thinness was offered at the various times when the ring was observed with the Sun and Earth on opposite sides of it. At such times, though the very oblique surface of the ring was visible, nothing could be seen of the edge of the ring itself, which should have been seen as a thin rim of light. This sunlit edge of the ring was not visible at any time, though it was always looked for carefully when the seeing was best.

As it may be important for the aid of others in any investigation of the phenomena presented by the ring in 1907, I may be permitted to copy here my previous measures of the Saturnian system; to these I will add the measures of the condensations. They are all reduced to the mean distance of Saturn from the Sun = 9·5389. (See *M.N.*, vol. lvi. p. 171.)

Table of Measures of the System of Saturn.

Equatorial diameter of Saturn . .	17″·800	Radius	8″·900
Outer diameter of outer ring . .	40·108	,,	20·054
Inner diameter of outer ring . .	35·046	,,	17·523
Centre of Cassini division . .	34·517	,,	17·258
Outer diameter of inner ring . .	33·988	,,	16·994
Inner diameter of inner ring . .	25·647	,,	12·823
Inner diameter of crape ring . .	20·528	,,	10·264
Width of Cassini division . .	0·529		

Inner condensations from limb . . .	2″·706	{ from centre of planet }	11″·606
Outer edge of inner condensations from limb	...	,,	12·900
Inner edge of outer condensations ,,	...	,,	15·200
Centre of outer condensations . ,,	7·438	,,	16·338
Outer edge of outer condensations ,,	...	,,	17·480

The polar diameter of Saturn was 16″·241.

The measures of December 12 made the length of the outer condensations $=[2''\cdot28]$, and the distance between their nearest edges $=[2''\cdot30]$. From these and the tabulated position of the centre of the outer condensations we have the values of the positions of the ends of the condensations as given in the table. The observations show that the condensations on the preceding and following ansæ were perfectly symmetrical with respect to the centre of Saturn.

If now we compare the full extent of the outer condensations with the Cassini division we have—

Outer edge of outer condensation from centre .	17″·48
Outer edge of the Cassini division . . .	17·52

Likewise we have for the inner condensations—

Outer edge of the inner condensation . . .	12″·90
Outer edge of the crape ring	12·82

These would seem to connect the condensations directly with the Cassini division and with the crape ring.

They are opposed to the supposition that the bright part of the inner bright ring is responsible for the outer condensations, for they show that the outer condensations extended beyond this ring.

I believe it has been shown that the Cassini division must be free of particles, because of the disturbing action of certain of the satellites. If this were not so, and the Cassini division were filled with particles as closely clustered as they are in the crape ring, a satisfactory explanation of the condensations would be that they

were simply due to the sunlight shining through and illuminating the particles in the crape ring for the inner condensations, and a similar effect of the Sun shining through the Cassini division and illuminating the particles in it would produce the outer condensations.

The fact that the inner and outer condensations were essentially of the same intensity would require that the particles should be as closely clustered in the Cassini division as they are in the crape ring.

With the assumption that particles do exist in the Cassini division, the above explanation of the condensations would be satisfactory.

In any attempt to connect the inner condensations with the crape ring, it may be important to state that these condensations have always appeared much brighter than the crape ring has ever appeared to me—even allowing for that ring being ordinarily seen between two bright regions, the inner bright ring and the ball of Saturn.

In conclusion, I am greatly indebted to Professor Frost for the extra time with the 40-inch to observe the phenomena of the disappearances and the reappearances of the ring of Saturn, and for the kind interest he has shown in the work.

Yerkes Observatory,
Williams Bay, Wis.:
1908 *January* 10.

A few Observations of the Planet Saturn and his Rings in the Years 1897–1904. By E. E. Barnard. (Plate 11.)

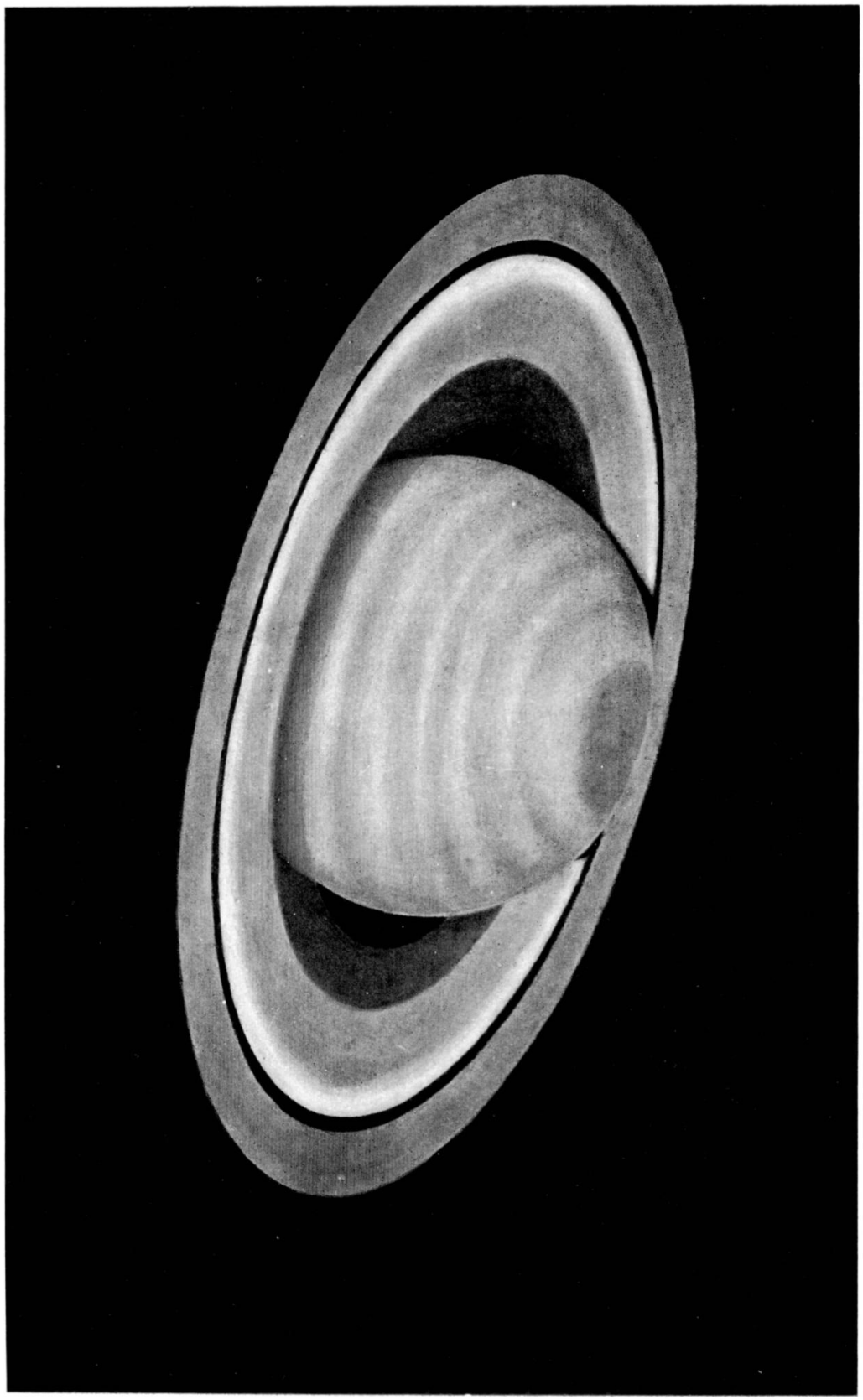
In connection with the papers on the disappearance of the ring of Saturn, I have thought it might be interesting to include in a separate short paper some other notes on the planet.

I have a number of observations of Saturn made here in the past ten years. Some of these are perhaps worthy of record, as they bear on the appearance of the planet with the large telescope when the rings were wide open, and I have collected a few of them for this paper.

1897 May 24. The north polar cap of Saturn was of a bluish dark colour—not well seen. It was bordered by a light belt.

1897 July 1. (With the 12-in. telescope.) The rings were opened so that their outer edges seemed to be exactly coincident with the polar limb of Saturn. It appeared perfectly so on this date, and also on June 29. The shadow of the ball on the rings seemed to be "squarey" where it struck the Cassini division. The polar cap was dark grey and not large. It was bordered by a light space, then a delicate dark narrow belt. There was no light equatorial zone.

I think this angular or "squarey" form of the shadow of the ball on the ring was simply caused by the shadow falling on the



SATURN.

With the 40-inch refractor of the Yerkes Observatory, 1898 July 7, 9 h. 20 m.—E. E. Barnard.